Synopsis V1.0
Single Event Effects and Total Ionizing Dose Testing of the
Unitrode UCC1806 Pulse Width Modulator Controller

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TID Test Dates: August 27 – September 4, 2003   Report Date: March 22, 2004

I.   Introduction

This study was undertaken to determine the single event destructive and transient susceptibility of the Unitrode UCC1806 Pulse Width Modulator Controller. The device was monitored for transient interruptions in the output signals and for destructive events induced by exposing it to a heavy ion beam at the Texas A&M University Cyclotron Single Event Effects Test Facility.

II.   Devices Tested

The UCC1806 Pulse Width Modulator controller is a BiCMOS version of the UC1846 family of PWM controllers. These are integrated current-mode PWM controllers with dual high current FET drivers. They have on-board oscillator, error amplifier, current-sense amplifier, voltage reference with external output, shutdown input, current-limit input, and separate internal supply and output drive supply. They are available in a DIL16 package as well as the package used in this testing, a PLCC20.

The sample size used during both SEE and TID testing was three devices, for a total of six devices. The devices were manufactured by Unitrode and were characterized prior to exposure. The devices tested had a Lot Date Code of 0126. All DUTs' package markings were identical and are given in the table below:

TOP	BOTTOM
UCC1806J/883	113088T EA
34333 PHIL	PHILLIPINES
? 1A0126PQ	

III.   Test Facility

Facility: Texas A&M University Cyclotron Single Event Effects Test Facility,
         15 MeV/amu tune.

Flux: 1.0×10^3 to 1.3×10^5 particles/cm²/s.

Ion	Incident LET (MeVcm²/mg)
Ar	8.7
Cu	20.7
Kr	29.3
Xe	53.9

IV.   Test Methods

The test circuits were derived from the end application. The internal circuitry is run off of 12 V_{dc}. The outputs are run off of current-limited 12 V_{dc}. The SEE test circuit utilizes a –12V V_{ee} for trim, mimicking the application circuit, but as this was later deemed spurious to testing, the TID circuit was later designed without that trim voltage. The application circuit is designed to free-run at just below the system sync frequency of 200 kHz but no synchronization pulse train was used in this testing in order to allow visibility into the oscillator's radiation performance. An external DC voltage error signal applied as an open-loop input to the circuit. The outputs in the application drive a monolithic FET driver IC but in this application they drive a resistive divider. Initially it was envisioned that the resistive divider would feed a 74HC gate buffer but ultimately a resistive division probe was used for output monitoring, providing for remote probing of the signals with high bandwidth.

The SEE circuit was designed to mimic the application circuit and provide for monitoring of the output waveforms, in addition to the power supply current draw (accomplished simply by monitoring the GPIB linked power supply's output currents). The two output waveforms were monitored via two channels of a high-speed scope, and a variety of the scope's triggering modes were used to detect error conditions.

A separate TID circuit was designed to more closely monitor TID-related parameters, such as input bias currents into the differential error amplifier and current-sense amplifier. This was done by inserting series sense resistors in front of each of the inputs and measuring the DC voltage across them. V_{ref} was also monitored for variation, as well as the nominally-low, internal-circuitry supply current. The output circuit's supply current was likewise monitored. The output waveforms were not examined for most of the conditions of import in SEE testing but were monitored only for frequency and duty cycle. The circuit was biased and operating and was monitored during Co-60 gamma irradiation.

The appendices include the part datasheet as well as a representative schematic for the SEE testing and one for the TID testing.

V.   Results

Single Event Latchup

Three parts, biased at nominal voltage (12 volts), were tested with heavy ions with LETs ranging from 8.7 to 76.2 MeV-cm^2/mg, with at least 10^7 ions/cm^2 at each LET value. In no test condition were any high current conditions observed that would indicate any latchup or other destructive mode. Therefore, the UCC1806 is considered to have an LET threshold for destructive events of greater than 76.2 MeV-cm^2/mg.

Single Event Transients/Upsets

Normal outputs from the UCC1806 are shown in Figure 1. When exposed to the heavy ion irradiation, two primary modes of altering this output were observed. These were termed simple and dropout. A simple event is one in which the only observable difference is that one to a few output pulses are either shortened or missing. The dropout event is one in which the two channels disappear completely for an extended period of time.
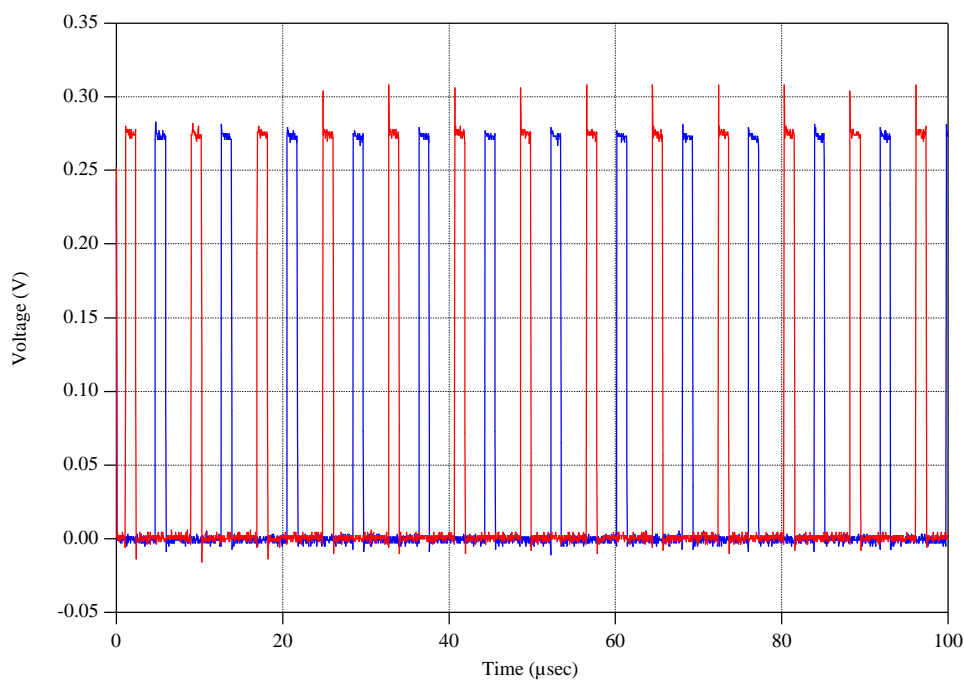

Figure 1. Pre-rad traces for normal operation.

Sample output for each of the modes of upset are given in Figure 2 through Figure 4. Figure 2 and Figure 3 show the four samples of the simple type of event. Figure 4 shows two samples of the dropout type event. The bottom figure here shows that the dropout duration is typically on the order of a few milliseconds.

The second issue to deal with in transient/upset characteristics is the cross section. Figure 5 and Figure 6 show the cross section curves for the simple and dropout events, respectively. Weibul fits to these data sets are also plotted, as appropriate. The dropout events have a threshold LET of approximately 9 MeV-cm^2/mg and a saturation cross section of approximately 1.7 x 10^{-4} cm^2. The combined simple and dropout events have a threshold LET of approximately 1 MeV-cm^2/mg and a saturation cross section of approximately 1.0 x 10^{-3} cm^2. It should be determined from this that the simple events have the LET threshold of approximately 1 and saturation cross section of approximately 8.3 x 10^{-4} cm^2. It should be notes that the high LET data points in the "All Events" plot were not included in the Weibull curve fit as these were data points taken with trigger setting that reduced the number of simple events captured.
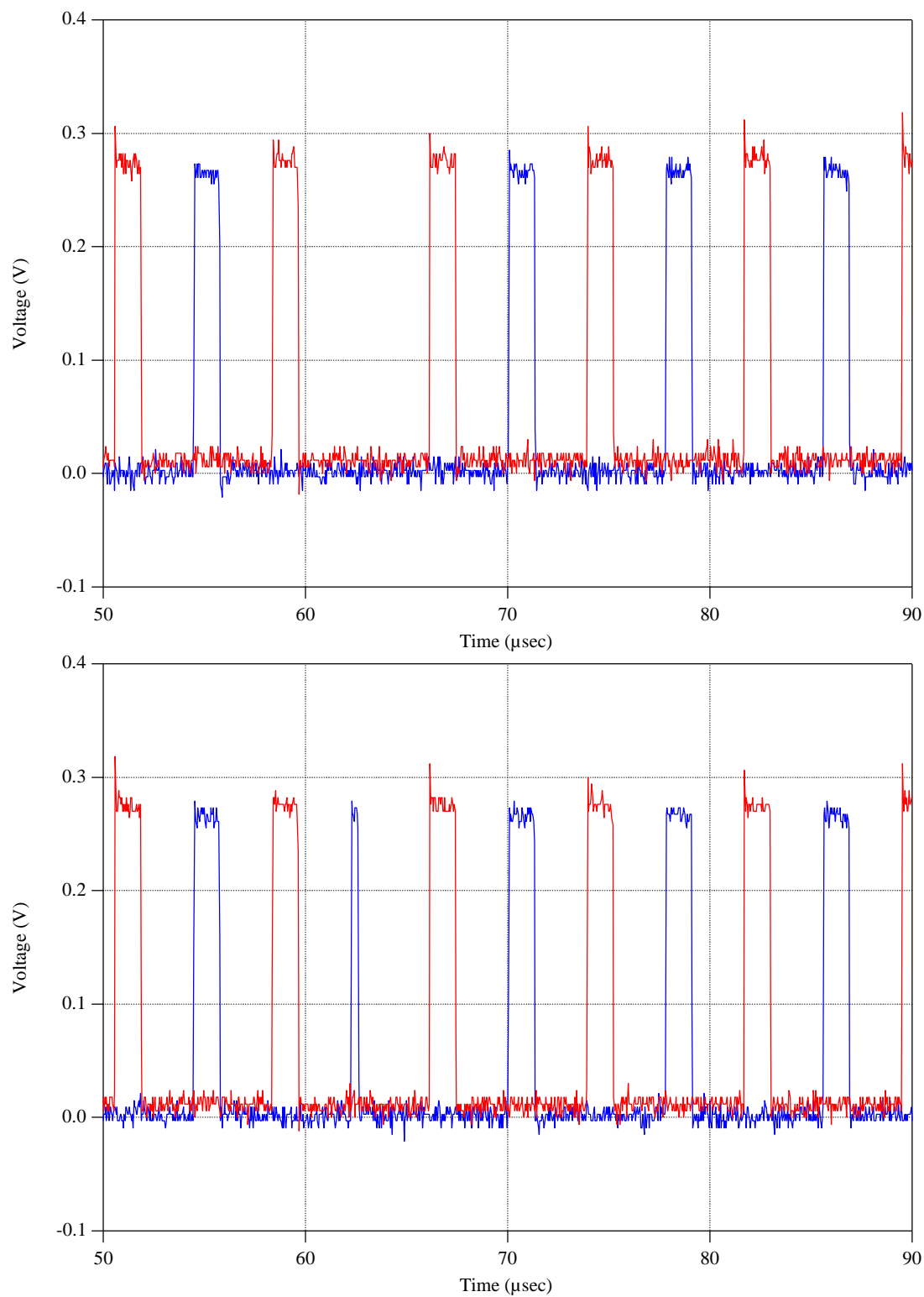
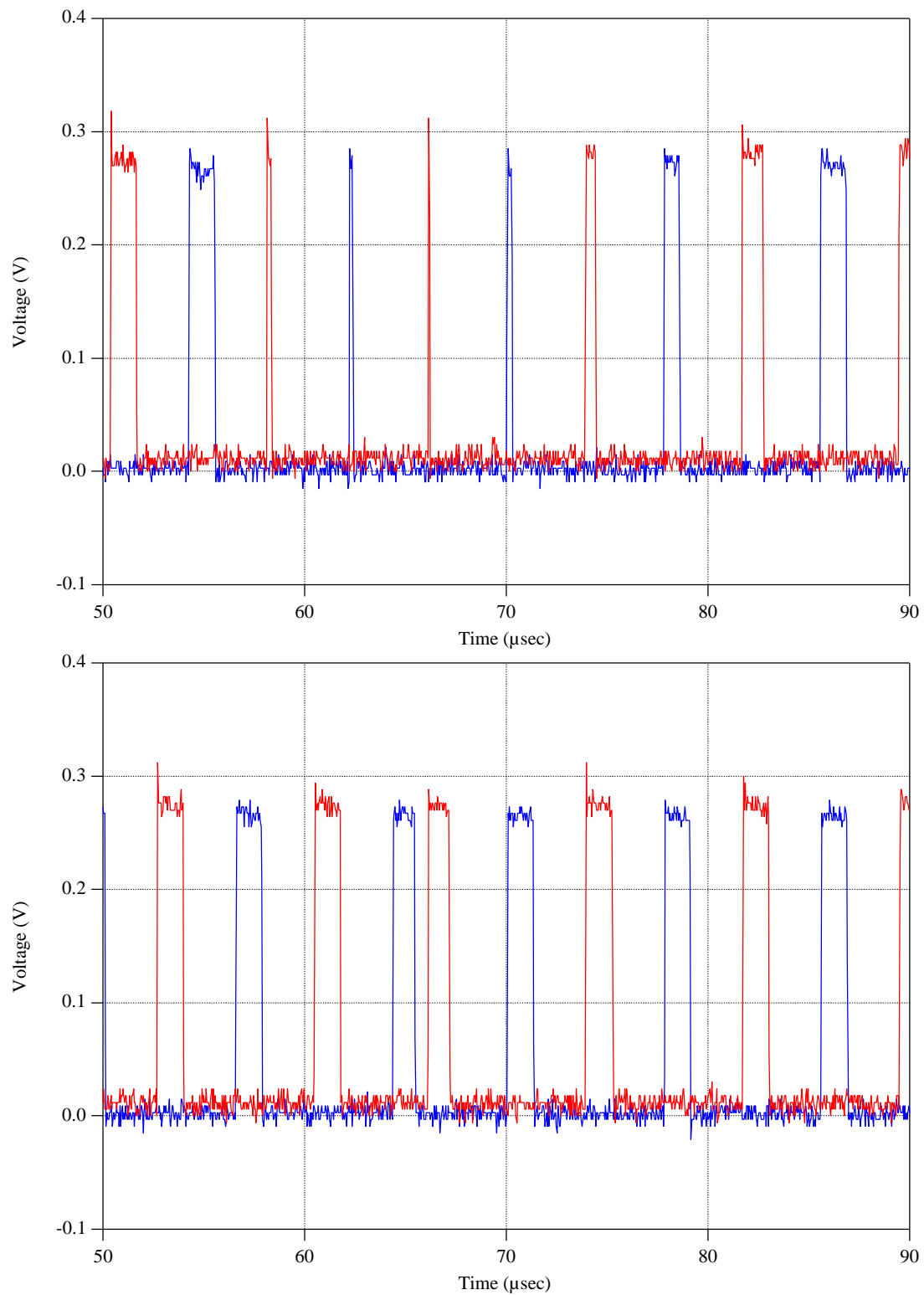Figure 2. Sample outputs showing shortened or missing pulses (simple events).

Figure 3. Top figure shows a shortening of more than one pulse and the bottom shows a temporal offset of one pulse (still considered simple events).
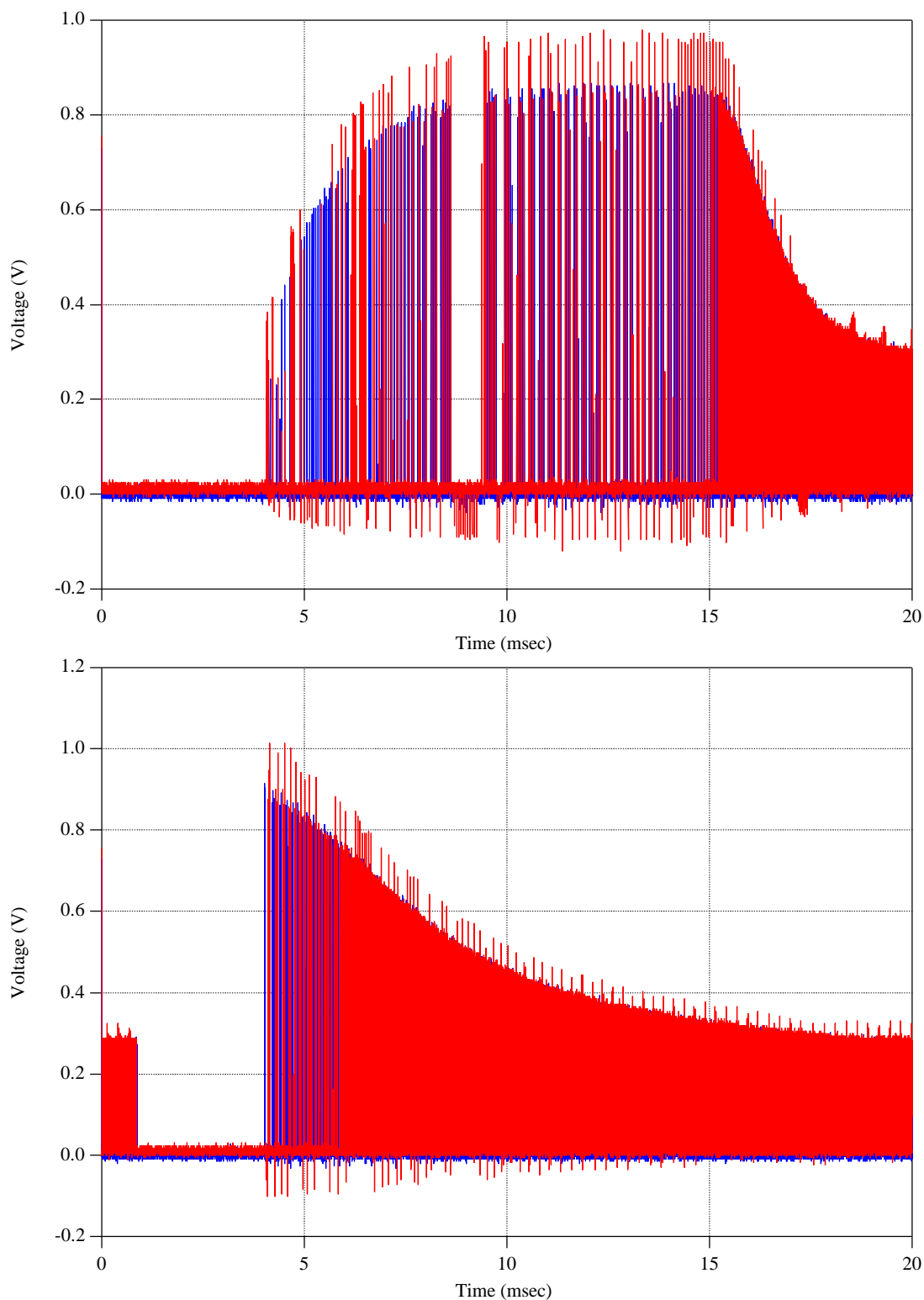
Figure 4. Sample outputs showing the dropout type event. The bottom event shows the full duration of the dropout while both show the voltage overshoot (to nearly a volt) that the output goes to during the recovery phase.
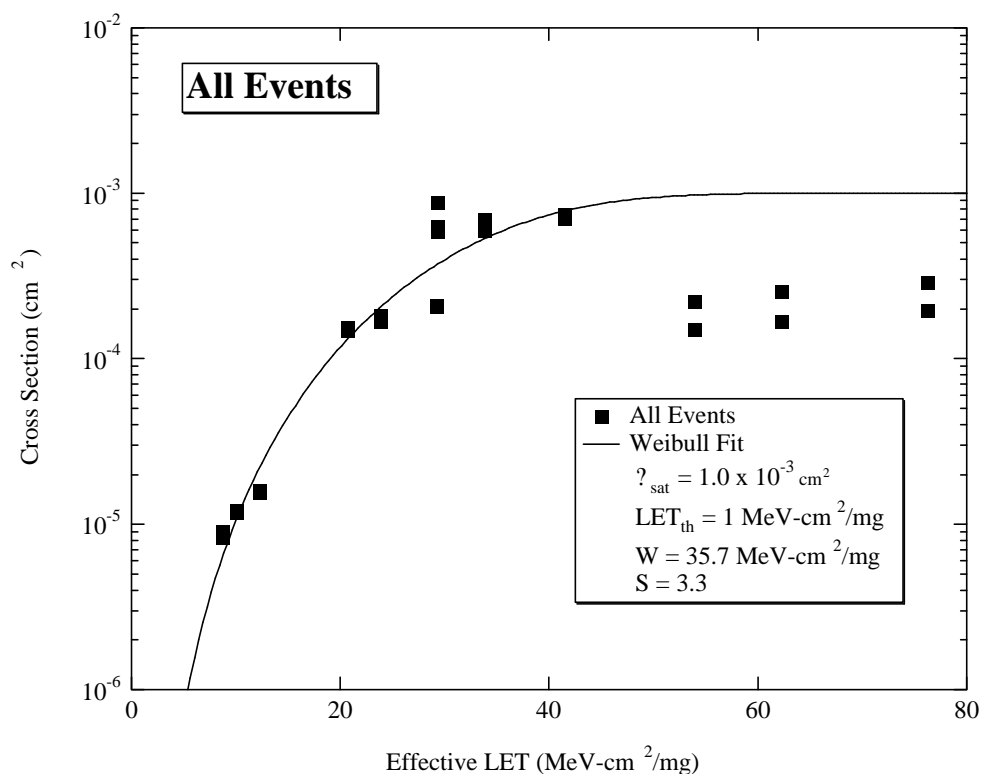
Figure 5. Cross section versus effective LET curves for all events, including both simple and dropout events.
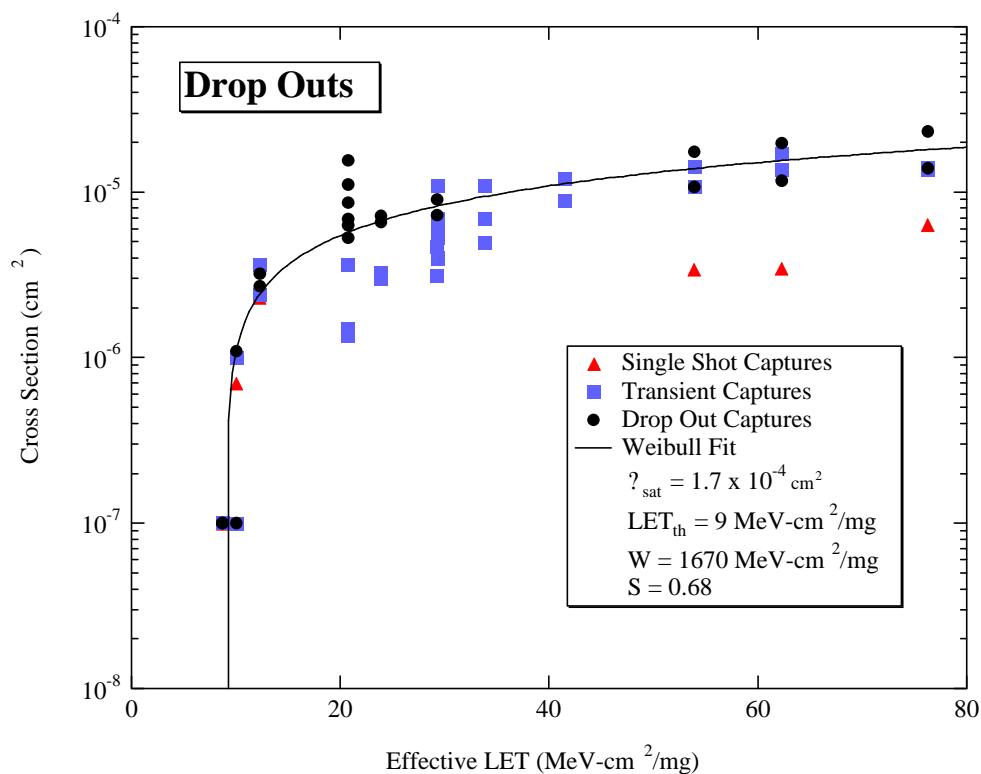

Figure 6. Cross section versus effective LET curves for only the dropout events.

Total Ionizing Dose

Three devices were exposed sequentially (due to the limitation of only being able to power and test one device at a time) to Co-60 at an exposure rate of approximately 1 krad/hour. All three devices behaved similarly in that all device parameters changed very little throughout the entire exposure conditions. However, after a dose level was achieved on each of the three devices, the device would functionally fail. For Device #1, it passed functionality at approximately 5 krads but failed at about 21.6 krads (functionality was not checked at intermediate values). Device #2, it passed functionality at approximately 7.5 krads but failed at about 27.6 krads (functionality was not checked at intermediate values). Finally, Device #3 was functional through approximately 26.2 krads but failed after 50.8 krads. While not a complete data set, the trend for the devices is sufficient to indicate that functional failure does occur in these devices between 20 and 30 krads and there is no parametric shifts of any significance prior to this failure point.

VI.   Recommendations

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1 – Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2 – Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3 – Recommended for usage in some NASA/GSFC spaceflight applications, but requires extensive mitigation techniques or hard failure recovery mode.
Category 4 – Not recommended for usage in any NASA/GSFC spaceflight applications.
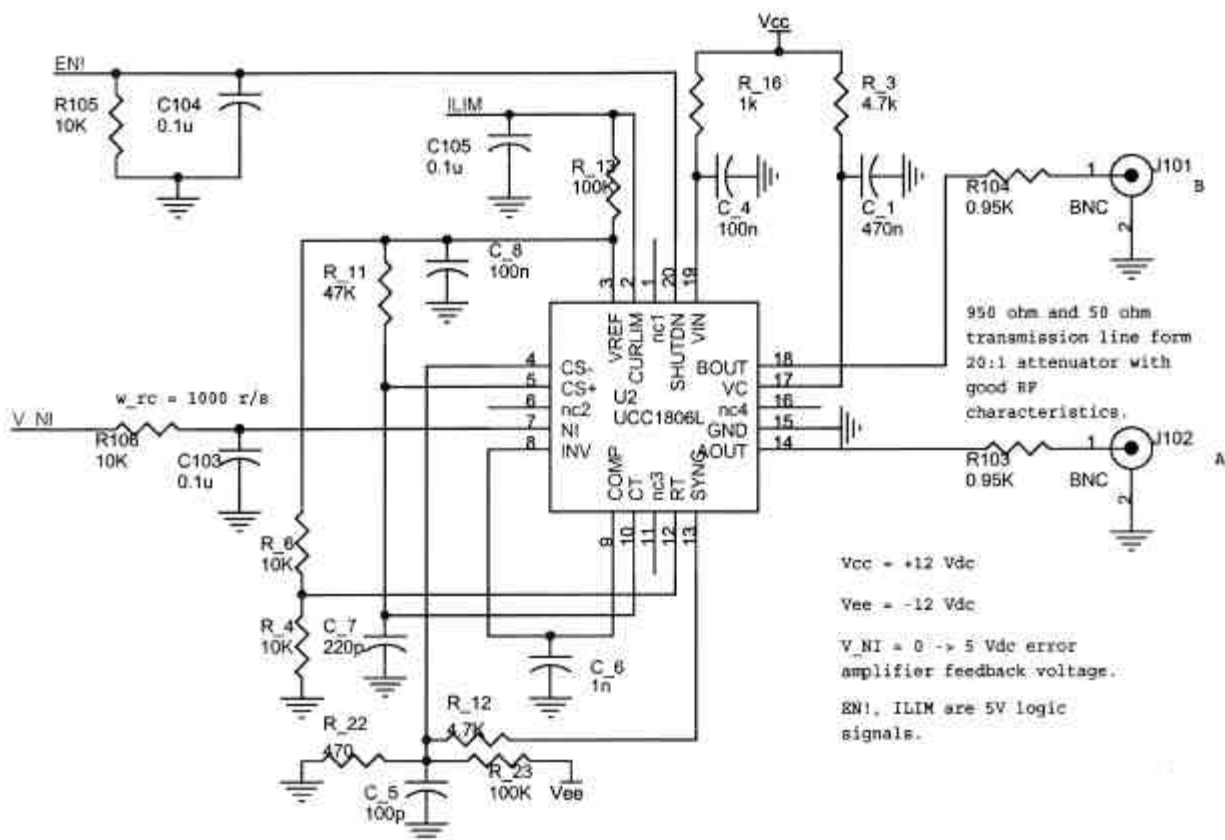
The Unitrode UCC1806 Pulse Width Modulator Controllers are currently considered Category 3 devices. If, however, the dropout events observed can lead to destructive operation and their cross section increases with addition heavy ion or proton testing, the UCC1806 could become a Category 4 device.

Appendix A
(Add Datasheet)

Appendix B
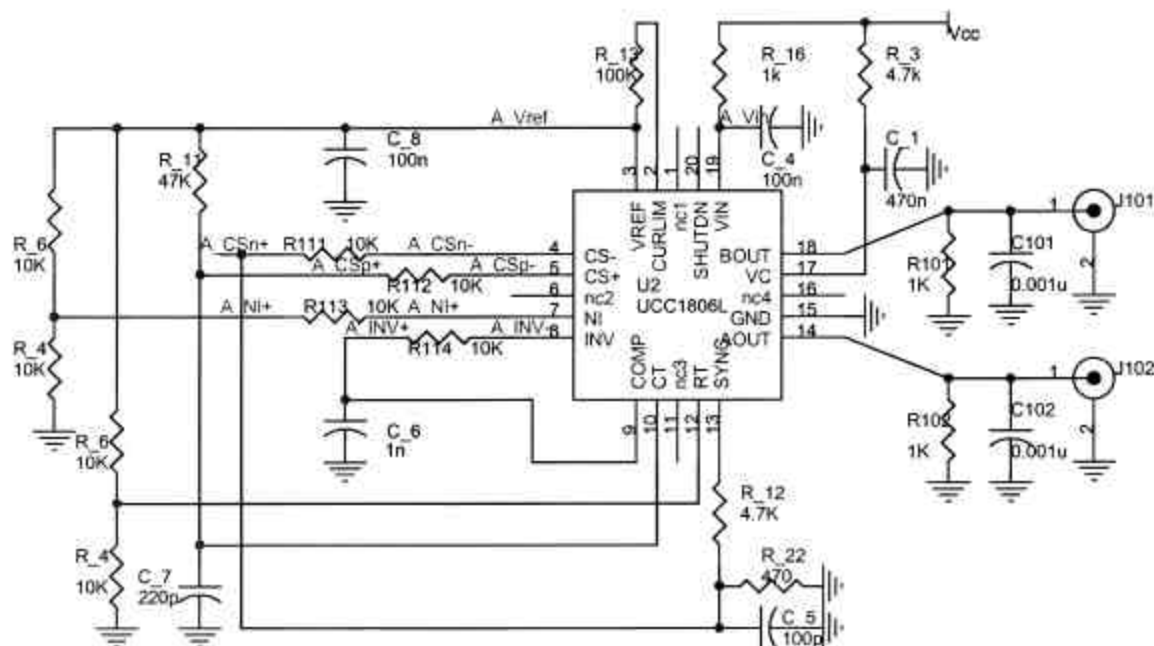
SEE Test Circuit

TID Test Circuit